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Columbia



AQUATIC RESOURCES PLANNING REPORT

Prepared for

SCIENCE COUNCIL OF BRITISH COLUMBIA
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EXECUTIVE SUMMARY

In response to direction from the Science Council of B.C., a sector planning committee met to identify priority needs for research and development in the aquatic resources area to contribute to the economic development of B.C. Our examination led us to the conclusion that substantially increased levels of R & D funding are needed to realize the potentially large economic development benefits from this sector. We recommend that the allocation of such R & D funding respects the following priorities.

Aquaculture: Current investment of more than \$300 million and the prospect of substantial employment opportunities were key factors in identifying aquaculture as the most promising area of economic development. Aquaculture R & D priorities were identified as follows:

- **Salmon Farming:** Genetic selection of better farm stock; improved diets; and solutions to a variety of disease problems, especially bacterial kidney disease (BKD).
- **Shellfish:** Additional R & D on reproduction, hatchery and nursery technology; genetic improvement; improved processing and handling.
- **Product Diversification:** Projects whose objectives are the introduction of new aquaculture species.
- **R & D** whose objective is to alleviate the negative impacts of natural processes on aquaculture crops (e.g., diatom blooms, shellfish toxins).

Other Aquatic Sector Industries: The following priority R & D needs for B.C.'s aquatic sector industries other than aquaculture were identified:

- **Water Quality:** The mitigation of natural processes or man-made contamination that cause adverse impacts on living aquatic resources, such as undesirable plankton blooms and chemical toxicants. The environmental impacts of aquatic resource industries also need to be examined.
- **Aquatic Instruments:** Continued support for new instrumentation, especially technology involving optical fibres and hydroacoustics. It was noted that better cooperation between government, universities, and the private sector would greatly enhance R & D in this area and that availability of venture capital for commercialization of promising prototype instruments or devices was a serious problem.

- Fish Harvesting and Processing: R & D whose objectives are to improve harvesting, pre-processing and transport, product yield, quality, shelf life, and packaging are all potentially promising areas for B.C.'s fishing industries. In addition, the improved utilization of fish by-product, the commercial development of under-utilized marine resources, and better communication between harvesters and processors are other important areas where improvements are necessary.

In addition to R & D priorities, the Aquatic Resources Planning Committee reviewed existing aquaculture-related R & D and education activities in British Columbia. The committee strongly believes that realization of the enormous potential from aquaculture will require the coordinated efforts of the private sector, educational institutions and government agencies. An Aquaculture Network of Excellence with appropriate funding is proposed whose primary mandate would be to foster collaborative and cooperative research in support of the aquaculture industry.

INTRODUCTION

The Science Council of British Columbia established a series of sectoral planning committees in early September 1987 to identify opportunities for economic development within the province. These committees comprise representatives of industry, research institutions, and government, and they are to develop specific sectoral plans for the application of science and technology. The recommendations of each committee will then be reviewed and priorities established by Science Council and integrated into overall plans for science and technology.

The following individuals were members of the Aquatic Resources Sector Planning Committee:

Leo Margolis (Chairman)	Dept. of Fisheries and Oceans, Canada
David H. Barbour	Fisheries Council of British Columbia
D. Harold Copp	Science Council Liaison Member
T. Gordon Halsey	Ministry of Agriculture and Fisheries, B.C.
John E. McInerney	Biology Department, University of Victoria and Bamfield Marine Station
Brian A. McKeown	Biology Department, Simon Fraser University
Donovan F. Miller	Science Council Liaison Member
Daniel K. Nomura	Canadian Fishing Company, Vancouver
Timothy R. Parsons	Dept. of Oceanography, University of B.C.
William Pennell	B.C. Salmon Farmers Association
Ronald G. Perkin	Dept. of Fisheries and Oceans, Canada
Norman J. Wilimovsky	Resource Ecology, University of B.C.

This report is divided into two major sections. The first discusses a strategic plan for additional research and development within the aquatic sector, including research needs, constraints to further research, and specific recommendations of the committee in each of five areas expected to benefit the most from future R & D activities. The order of discussion of these areas does not infer any implied order of priority for further R & D within the aquatic sector. Similarly, lists of recommendations presented throughout various report sections should not be interpreted as being in order of priority.

The second section of this report discusses the rationale for and the potential scientific and economic benefits of a Network of Excellence that should be established for aquaculture within British Columbia.

There is considerable scope for interaction between R & D activities relevant to the aquatic sector and those of other B.C. industry sectors under review by Science Council.

PART I

AQUATIC SECTOR RESEARCH & DEVELOPMENT PLAN

DEFINITION OF AQUATIC RESOURCES SECTOR

The Aquatic Resources Sector Committee is responsible to the Science Council for the evaluation and ranking of research and development proposals in this subject area. Although the sector is broadly defined to include all forms of living aquatic resources, the aquatic environment, and aquatic instrumentation, the criteria established by the Science Council generally limit its support to proposals of a research and development nature that involve the application of science to commercial endeavours in British Columbia and to a lesser extent, Canada and the resource area as a whole. Although adjudication involves economic, social, and institutional factors in evaluating the potential success of a proposal, it does not generally recommend studies specifically treating those issues or areas of a more indirect benefit such as sports fisheries. Projects that are the direct responsibility of government agencies (e.g., salmonid enhancement and fisheries management) also are not considered by Science Council.

These general criteria were followed in identifying those areas of the aquatic resources sector of British Columbia likely to gain the most from short- and medium-term investment in R & D activity. The resulting areas and their definitions for this particular purpose are presented below (in some cases, the definitions are more restrictive than those that generally appear in public documents).

The Committee recommends that industry be consulted regularly and in a meaningful matter to determine research needs and priorities. This process is implied throughout this report which has benefitted from significant industry advice.

Water Quality - The science concerned with changes in the physical, chemical, and biological characteristics of water due to natural or pollution-related inputs of various elements, compounds, or substances.

Aquatic Instruments and Devices - The industry that develops and markets new aquatic instruments and devices through application of existing or new technology.

Fish Harvesting - The industry involved in the capture or collection of aquatic organisms (finfish, shellfish, and marine plants) and transport of these resources to processing facilities or markets.

Fish Processing - The industry that processes harvested fish and other marine organisms to yield marketable products and by-products.

Aquaculture - The industry concerned with the culture of aquatic organisms (finfish, shellfish, and marine plants and extracts).

Based on statistics available from the Ministry of Economic Development, the total wholesale value of all aquatic sector industries in B.C. during 1986 was greater than \$750 million.

CURRENT STATUS AND FUTURE OF THE AQUATIC RESOURCES SECTOR

Water Quality

Background

The scope of this section is limited to consideration of R&D needs with respect to the impact of water quality on aquatic resources and the impact of aquatic resource industries on water quality.

Unlike many marine environments near urban and industrialized areas elsewhere in the world, there is a comparatively low risk of long-term accumulation of pollutants in most B.C. coastal waters. This is because of the relatively high flushing (water exchange) rates for such a large body of water and relatively low human population density. This not only prevents a progressive increase in contaminant concentrations in sea water, but also dilutes and disperses potentially hazardous materials. For example, the waters of the Strait of Georgia are replaced on an average of at least once a year, while flushing rates are expected to be even more frequent in exposed environments such as the outer coast of Vancouver Island and in many parts of the North Coast of B.C. In contrast, the water exchange rates in the Baltic, Mediterranean, and Black seas are 25, 70, and 3000 years, respectively.

Contaminant inputs may, however, be a local concern in some sheltered environments such as harbours or coastal bays with limited water circulation. In these areas, there is a far greater potential for pollutants to reach toxic concentrations within the water column or seafloor sediments when contaminant inputs occur on a continuous or intermittent basis (i.e., chronic exposure conditions exist). Historically, the sources of local pollution in B.C. have been: domestic sewage (coliform bacteria, heavy metals, and nutrient input leading to eutrophication); pulp mill effluents; chloralkali plants; petroleum refineries and marine vessel operations (hydrocarbons); agricultural runoff (often containing nutrients and pesticides); and logging operations (leachates and other organic materials). Contaminants are regulated and monitored under federal and provincial waste management legislation.

In addition to the above, many inlets are susceptible to and have experienced various undesirable plankton blooms in the past, including red tides and the diatom Chaetoceros convolutus.

Research Needs

Research needs related to water quality and long-term pollution hazards in B.C. coastal marine environments will depend on industrial growth in B.C. The most significant local concerns that may require further investigation are: (1) the potential effects of relatively new contaminants originating from changes in the use of industrial chemicals paints (e.g., tributyl tin (TBT)); (2) adverse impacts of aquaculture operations in areas

with limited water circulation; and (3) the natural occurrence of undesirable plankton blooms. In the first case, concern exists because of very limited available information on the long-term fate and effects of such new contaminants within aquatic and marine ecosystems. In the second case, local eutrophic conditions may develop in areas with limited water exchange because of nutrient enrichment associated with accumulation of feed, waste products, and dead fish beneath aquaculture pens. Research in this area should be balanced against mitigative measures which might be taken to prevent the occurrence of eutrophication. The third area of concern and research need requires some predictive capability related to potential bloom conditions so that mitigative measures can be taken where possible before the occurrence of an algal bloom. The quality of freshwater supplies may also be a concern in some areas, particularly when it is required for aquaculture purposes.

While it is important for Science Council to fund research in these areas, any risk to public health should be determined by public health authorities.

Constraints to Further Research

One possible constraint to additional research within the water quality sector relates to jurisdictional questions among federal, provincial, and municipal authorities regarding responsibility for research associated with various forms of industrial and domestic pollution.

Recommendations

1. Any large-scale development that may result in localized decreases in water quality should be the subject of further research to determine its potential impact on existing and historical uses of the B.C. coast for fisheries and recreational purposes. This recommendation must take into account existing research projects in the area of marine pollution.
2. Research should be initiated in conjunction with major aquaculture projects that could adversely affect water quality through localized nutrient enrichment, or when there is an anticipated widespread use of any new chemical that may accumulate to a significant degree in aquatic environments as a result of chronic inputs from terrestrial (e.g., pesticides) or aquatic (e.g., tributyl tin) environments. The latter portion of this recommendation should take into account existing research projects as in 1 above.
3. Research on harmful plankton blooms should be undertaken in cooperation with federal and provincial agencies that are concerned with this problem.

Aquatic Instruments and Devices

Background

In the past decade, B.C. firms have been very active in the development and marketing of new aquatic instruments and devices. Some products are developed to satisfy needs in a field such as aquaculture and involve the use of existing technology. In other instances, these instruments/devices apply previously unknown phenomena (e.g., chemical sensitivity in optical fibre coatings) or adapt novel methods to the ocean environment (e.g., use of plasma discharge to generate an acoustic pulse). The latter may be a significant advance on existing products or completely new products capable of generating their own international markets.

Some B.C. firms are considered in the world forefront in several areas of instrumentation technology, particularly in the development of fibre optic sensors and hydroacoustic devices. Local R & D companies have also supported the aquaculture industry through the design of cost-effective alarm and monitoring systems. The R & D activities of these firms may also have positive spin-offs to other aspects of their operations. Several companies have divisions or affiliates engaged in environmental consulting or engineering and may use their own products in a variety of research or monitoring applications.

It is emphasized that this instrumentation industry is an integral part of all aquatic sector industries in B.C. Each of the industry sectors discussed in this report relies to some degree on instruments or devices produced by local R & D firms.

Research Needs

This sector is profit-driven and considered largely successful. Nevertheless, there are several areas where further R & D activities are expected to produce positive benefits.

Sensors - A large demand for sensors with data handling abilities is expected. To ensure success in world markets, these devices must be fully developed and engineered rather than prototypes with limited field testing time. Development of sensors using optical measurement techniques coupled with optical fibre transmission is the most quickly advancing field in this area. The use of chemically-sensitive coatings on optical fibres to measure oceanographic and water quality variables is a promising area of future research.

Acoustics - Acoustic technology is used to assess fish stocks, measure water depths and current fields, transmit data, conduct seismic profiling, and position offshore structures and vessels. Intensive computational tasks can now be completed by some acoustic devices with signal processing capacity. However, there is still a need for research in areas such as signal discrimination and use of multiple frequencies in acoustic

instrumentation.

Electronics - Many of the advances in aquatic instrumentation and devices in the past decade have resulted from progress in the electronics industry. There is still a need, however, to develop more reliable electronic instrumentation for use on ships and in moored arrays of oceanographic devices to minimize the risk of instrument failure. In addition, battery-powered devices with a lower power consumption are required for oceanographic research.

Navigation - Small and inexpensive receivers that access the Global Positioning System have been developed in recent years. New markets are expected for integrated instrument systems that combine position information with other data (e.g., drifting weather and sea-state buoys).

Robotics and Submersibles - R & D activities within B.C. have also focused on robotics and submersibles, which have some applications in ocean mining, underwater inspection, and scientific research. However, the major drawback to the use and further development of these devices is their high capital and operational costs in relation to possible returns.

There is also considerable potential for interaction of this sector with the electronics, manufacturing and perhaps other sectors in B.C. In particular, there may be future opportunities for cooperative R & D projects leading to the domestic and international marketing of aquatic instruments and devices that produce economic benefits in several sectors.

Constraints to Further Research

There are several limitations to future R & D activities in this sector. The first is that the market is currently saturated with some types of instruments such as depth sounders. As a result, there is little economic benefit to be gained from further research in such areas. An additional constraint is the capital commitment often required to take a prototype instrument to the stage where its reliability can be clearly demonstrated before marketing. Most funding agencies including the Science Council tend to support the early stages in the development of a new product. There is a serious need for more funds to take highly-promising products from the prototype stage of development to the point where they can be marketed.

Other constraints relate to personnel available to work on R & D projects in this sector. There is a requirement for greater technology transfer and cooperation among government agencies and the private R & D companies. Greater involvement of government and universities would benefit R & D projects related to aquatic instrumentation. At present, there is a tendency for R & D firms to import expertise from outside Canada rather than rely on expertise available within the country. Development of the necessary specialists in the instrumentation field within B.C. and other Canadian universities would be highly desirable. This would stimulate greater cooperation among the universities, government, and private R & D organizations and would facilitate international technology transfer.

Recommendations

1. Development of devices and instruments supporting B.C. industries such as aquaculture, fish harvesting, and fish processing should continue to be given strong support.
2. Continued research effort should be directed at development of acoustics instrumentation and fibre optic sensors, particularly where there is a potential for export of these products to international markets.
3. Technology transfer and cooperation among universities, government agencies, and private sector R & D firms is essential and should be encouraged. At the same time, a concerted effort should be made to develop the expertise required to support continued growth and success of this industry through education programs at B.C. universities.
4. Sources of additional funds to take highly-promising products from the prototype to marketable stage of development should be sought.
5. Opportunities for cooperative R & D projects and interaction with the electronics and manufacturing sectors in B.C. should be examined.

Fish Harvesting Industry

Background

A fishery can be considered a system involving biological, technological, and social-institutional components. The second of these components is the focus of this section and comprises three primary activities: harvest, processing and distribution. Only the harvest activity is discussed here and includes search, identification, and catch operations. The search component of the harvest involves the location of target stocks and is dependent largely on the abilities and experience of individual fishermen. Depending on the stock, identification activities generally involve the use of sonar and other techniques to estimate the size composition of a stock, and are important to assess if harvest effort can be justified. The actual catch operation includes setting, soaking and hauling of gear, as well as subsequent treatment of harvested fish for transport to processors or fresh-fish markets.

The B.C. fishing industry is overcapitalized, highly regulated, and restrained through gear competition. These facts limit the potential for research and development activities relevant to this sector.

Research Needs

Primary areas of concern related to the fish harvest sector are the development of more efficient harvesting methods, maintenance of fish quality in the transport of fish to processors, and communications. There is a need for R & D activities in these areas.

Alternative Capture Methods - Development of alternate fishing gear types to reduce damage and loss of quality resulting from capture needs urgent attention to address concerns of the processing industry. These might include use of acceptable traps and pumps, as well as fish aggregating devices (FADs) such as lights.

Pre-processing Transport of Fish - Because existing regulations or legislation in B.C. limit the amount of processing at sea, fish are initially treated by either cooling or freezing. Further information is required on these initial treatment processes because it is likely that the rate of cooling, final temperature, and distribution of temperature within the catch are all important for maintenance of the quality of fish flesh. In particular, there is a need for measurement criteria and standards related to storage temperature and optimal packing (density) of the fish mass to maintain quality during transport. The method used to catch fish may also influence any deterioration of fish quality in transport.

Communications - Further advances are necessary in the exchange of information between vessels and processing facilities, particularly in terms of catch composition and size as well as the tracking of vessels to plants. The technology for tracking already exists, but is not being used effectively by either the fish harvest or processing sectors. More effective fish sizing

and product characterization methods are also required so that this information can be provided in advance to processors.

There is a high potential for interaction of this sector with the electronics industry in B.C.

Constraints to Further Research

Overcapitalization of the fishing industry and existing regulations that limit the efficiency of fisheries are known constraints to further research in this sector. These and a complex of other social factors influencing technological improvement in the harvest of fish resources have been discussed in numerous reports.

Recommendations

1. Special emphasis should be given to development of new, more effective and selective harvesting and pre-processing methods. Major efforts are needed to eliminate potential disincentives arising from existing regulations and harvest techniques.
2. Further research should occur in applying communications technology to the issues referred to above (composition and size of catch, vessel tracking), using existing technology to enhance information exchange between the harvest and processing sectors.

Fish Processing Industry

Background

This report section deals only with the traditional fish processing industry. Processing related to cultured fish, shellfish, and aquatic plants is discussed later in a section on the Aquaculture Industry.

Commercial fisheries and the fish processing industry account for a significant portion of the B.C. economy. About 20,000 people are directly employed in the commercial fishing industry and a similar number derive income indirectly from this industry. In 1986, the total wholesale value of seafood products from B.C. commercial fish processors was approximately \$750 million.

Wild stocks of all species of Pacific salmon are commercially harvested, processed, and marketed. The value of Pacific salmon and roe herring products alone accounted for about 83% of the total 1986 wholesale value of B.C. fish products. Additional revenues resulted from the processing of halibut, groundfish, sablefish (black cod), and shellfish.

Fish processing encompasses those operations involved in the treatment of harvested fish and fish material to yield marketable products and a range of by-products. The primary operations are unloading, holding, cleaning, fresh packing, freezing, canning, smoking, salting, curing, reduction, reconstituting and several "value-adding" procedures. Much of the equipment and many of the methods used by the commercial fish processing sector have been in place for many years with little or no change. However, the industry recognizes that there are opportunities for improving the efficiency of various operations.

Apart from improving efficiency, the processing sector also has concerns related to maintaining quality of fish resources available for processing, as well as optimising the value of the relatively large quantities of by-product fish material currently available. Additional R & D effort will reduce processing costs, increase the yield, and improve the quality of their currently-produced fish products.

Research Needs

Several areas of possible future R & D activity are briefly described below. All are considered important to ensure continued growth and profitability of the industry.

Improved technology to increase the efficiency of fish processing (both product yield and quality) - Because of the high costs of fish (i.e., raw material) and labour, it is essential to maximize efficiency, thereby increasing yields and/or reducing costs. For example, the primary recovery from raw fish resources ranges from 62% for canned salmon to only 15% for roe herring. Incremental improvements in final product recovery will result in significant economic benefits to the B.C. commercial fish processing industry.

At the same time, increased processing efficiency will be reflected in higher fish quality; this is also important because consumer expectations for high-quality fish products have increased in recent years.

New fish products and by-products using presently under-utilized resources - The recovery of product from raw fish resources is very low for some fish species harvested in B.C. waters. For example, in the production of groundfish fillets, 75% of the raw material is not recovered in an edible form. This by-product level is as high as 85% with roe herring. The incidental harvest of non-target species ("by-catch") in trawl fisheries directed at various groundfish species is also a source of under-utilized resources.

Innovative techniques to improve fish quality and extend product shelf-life - There is increasing need for techniques to improve fish product quality and extend product shelf-life because of the greater consumer demand for fresh fish products in recent years. In view of the conclusion of Science Council of Canada that irradiation is a safe process, consideration should be given to the application of this technique to treatment of B.C. fish products.

Enhanced fish inspection techniques - There is a need for development of new techniques to accurately determine market grades of products, thereby increasing consistency and conformance to standards.

New packaging concepts for existing and future fish products - The packaging of fish products (e.g., convenience, portion size, product appeal packaging) is becoming increasingly important to consumers. Therefore, this should be an area of ongoing research and development.

Interaction with research in agriculture, biotechnology, and manufacturing would benefit developments in this area.

Constraints to Further Research

Two primary constraints to further research in this sector are associated with the processing industry itself. The sector is limited primarily by the availability of fish resources and high level of competition for the available resource. Yet it has been able to sustain a reasonable degree of economic viability. As a result, there is little incentive to change despite the recognition by processors that additional research may be of long-term value in terms of improving processing efficiency as well as product quality and yield. In addition, profit margins have been restricted because of the high level of competition, rising fish costs, and high labour costs. This significantly hampers the ability of the processing industry to fund its own research.

The lack of a government laboratory devoted to R & D in the processing sector is a constraint, but not an insurmountable one because there are existing facilities (e.g., B.C. Research and Department of Food Sciences, U.B.C.) where such research can be conducted. Furthermore, the expertise necessary to undertake further R & D related to fish processing is available within the province. Joint industry-government funded research programs are

considered a good approach to further R & D activity in this field.

As new techniques and equipment are developed, it is important that employees within the processing sector receive the appropriate training when and where necessary. There is also a need to provide training to all people involved in the industry (from fishermen to retailers) on fish handling methods that will extend quality.

Recommendations

1. Further research and development work should be conducted to improve the present processing technology by increasing the efficiency of operations. It is also important to enhance product quality and operational productivity. Techniques to extend fish quality and product shelf-life as well as procedures or instruments to determine accurately product quality also should be areas of further research and development.
2. Additional research should be conducted to determine methods for improving the utilization of the large volume of by-product materials resulting from processing operations, and to investigate possible alternative uses of presently unused fish biomass in a wider range of marketable by-products. At the same time, an effort should be made to determine possible uses for the by-catch taken in some fisheries, particularly those directed at groundfishes.
3. Changing market emphasis related to improved product quality, convenience, and diversity has led to a growing recognition by the processing industry of the potential benefits of R & D. Additional funding for R & D in this area is essential to meet these needs and keep the B.C. industry competitive in world markets.
4. Opportunities for collaborative R & D programs involving the processing industry, government, and academic institutions should be pursued in an effort to stimulate the necessary research in the above areas.
5. Additional research should be directed at the development of new fish products when these products will be of potential benefit to the fish processing industry as a whole.

Aquaculture Industry

Background

Over the past 15 years, there has been rapid growth of aquaculture, the fastest growing industry in B.C., particularly in salmon farming which has been the target for 95% of the total of more than \$300 million invested in this industry to date. During this period, three main research areas to resolve existing problems or to provide new opportunities have become evident in salmon farming (disease, genetics, and nutrition); they are briefly discussed in the following section. Considerable research effort has been and continues to be directed at salmon farming in this province and is discussed further in relation to a proposed "Aquaculture Network of Excellence" in B.C. (Part II).

Aquaculture operations directed at shellfish species are at present of lesser importance in the B.C. industry. There are moderate oyster, and small mussel, clam, and abalone culture facilities, but the industry has not developed to its potential. It is expected that the future value of shellfish aquaculture could approach that of production from salmon farms because conditions in B.C. are generally favourable for the culture of invertebrates. For example, the oyster industry has doubled in value and production in the last 2-3 years and continues to grow rapidly. Research conducted at the Pacific Biological Station also indicates that the potential for scallop culture in B.C. is high.

Salmon farming in this province is at a relatively early stage of development compared to the size of the industry in some other countries. Nevertheless, the following statistics clearly illustrate the size, present economic value, and rapid growth that is projected for salmon culture as well as oyster culture industries over the next few years.

The spectrum of research requirements directed at improving the cost effectiveness of aquaculture will necessitate a multidisciplinary approach that encompasses, for example, biological, engineering, social, and economic disciplines.

Investment in Aquaculture and Economic Benefits

- There has been considerable foreign investment in all sectors from farming to equipment manufacturing and services; there was an estimated \$50-100 million of foreign investment for the entire aquaculture industry in 1986.
- One half of the investment in grow-out sites is in seapen facilities. There were 797 net pen cages in use on the coast in October 1986, and of this total, 588 were of domestic origin. A total of \$6 million worth of cages had been sold to the B.C. industry as of this date.

- An investment of \$0.5-1 million per salmon farm is normal.
- The major aquaculture industry organizations have predicted that the wholesale value of their products will grow to an aggregate of \$194 million by the 1990s.
- This could be a billion dollar industry within the next two decades and has the potential for major expansion unlike other sectors such as forestry, agriculture, and mining.

Salmon Farming

- There were about 10 licensed salmon farms in B.C. in 1984; this number increased to 82 by the end of 1986, and by August 1987, a total of 123 tenures had been issued with an additional 133 applications under review.
- Farmed salmon production in B.C. was 397 tonnes in 1986 and is projected to be as high as 15,000 tonnes by 1990. The value of the 1986 production was \$2.9 million. This value is expected to increase rapidly because farmed salmon (2-4 years old) are only just reaching marketable size and there are increasing numbers of farms.
- In 1986, 2900 tonnes of salmon feed was supplied by domestic producers and about 2250 tonnes were imported. Up to 30,000 tonnes of feed will be necessary by 1990. Existing suppliers have sufficient capacity to support salmon production levels of at least 8000 t/year.

Trout Farming

- The trout farming industry has existed in B.C. for several decades at a moderate level of production and has recently shown signs of an increase in several regions of the province. In addition, the sale of trout fingerlings to salmon farms for salt water grow-out has also increased trout production.
- Most of the research needed by the salmon farming industry will also benefit the trout farming industry, which is working with similar species and techniques.
- The Western Trout Growers Association promotes the interest of the province's trout growers and makes representations to government expressing the needs of the industry including R&D needs. Membership has grown recently to include farms from several regions of the province.

Oyster Culture

- In August 1987, the oyster industry comprised 361 active tenures held by 223 growers utilizing 1532 hectares of foreshore. An additional 189 applications for shellfish mariculture tenures were under review at this time.
- Cultured oyster production has recently doubled to 3000 t/year, while production from wild harvests has declined from historic levels of 1200 t/year in the early 1970s to 500 t/year. Total value of the oyster industry in 1986 was \$3 million with most production coming from aquaculture. By 1995, cultured oyster production may reach 5000 t/year.
- The B.C. Oyster Growers Association is the oldest grower association in the province and is an advocate of the oyster growing industry. Research and other industry needs are articulated by the Association, which now includes producers of other shellfish species.

Employment and Support Services

- As of June 1986, about 500 people were directly or indirectly employed in the aquaculture industry. This number is expected to increase to 3500 continuing jobs by 1990.
- There is an increasing number of consultants in farm management and husbandry practices, and although the income generated by this support industry is not known, it is estimated to be in the millions.

Research Needs

The aquaculture industry has an enormous potential for producing long-term economic benefits, investment incentives, and employment opportunities in B.C. However, certain existing problems must be resolved to achieve this potential and to ensure continued growth and competitiveness of the industry in world markets. There is also a strong existing base in terms of facilities and expertise for further R & D activities related to aquaculture in the province, as well as substantial benefits to be derived by the industry from various areas of research.

The following sections identify research needs related to: (1) salmon culture; (2) invertebrate culture; (3) diversification of the aquaculture industry; and (4) interrelationships between aquaculture and water quality.

Salmonid Culture

Four primary areas in salmon culture where further research is required relate to genetics and biotechnology, disease, nutrition, and overall quality of salmon reared in aquaculture facilities.

Genetics and Biotechnology

At present, a concerted breeding program to produce smolts specifically suited for rearing on salmon farms is needed. Major goals of the breeding program should be the production of fish that show consistently high survival and growth rates and excellent market quality. In addition to breeding, further research in the area of chromosome and hormonal manipulations could eventually allow the industry to control more efficiently the sex of fish to increase yields. Gene insertions may also be important in the future as a rapid means of improving farm salmon stocks.

Disease

Bacterial kidney disease (BKD) is the most significant problem in salmon farming and presently results in a loss of 20 to 60% of the potential production of salmon between the smolt stage and harvest. In severe cases, the disease can completely eliminate farm profit. Although appreciable technology is in place for avoiding the infection (if rigorously applied), methods for the effective treatment of the disease are lacking. There are several research approaches to BKD control that should be pursued: vaccine development; antibiotic treatment of eggs, production ("grow-out") fish, and broodstock; husbandry strategies; development of improved diets; and improved disease monitoring.

Other bacterial disease problems (actual and foreseen) include vibriosis and furunculosis. Although vaccines have been developed for preventing *Vibrio* infections in farmed salmon, they are not always effective and further research is necessary to solve this problem. Treatments for furunculosis are available but additional research is required on methods of prevention such as use of vaccines.

Disease caused by "salmon lice" (parasitic copepods) is an emerging problem also requiring research on methods of prevention and control.

Nutrition

Between 40 and 50% of the operating budgets of salmon farms (\$10-30 million/year) is required for feeding of fish. Because fish health is closely linked to the quality of food, there is a requirement for further research in this area, including needs to improve feed quality and reduce feed costs through efficient formulation. The inclusion of vegetable-based protein in the diet of farm fish is also expected to be an important ongoing research area. Considerable effort should be directed at increasing the efficiency of salmon-farming technology in B.C., particularly in terms of the nutritional requirements of pen-reared salmon. At the same time, there are opportunities

for improvement of feed delivery systems to minimize accumulation of un-ingested food pellets beneath sea pens. The need for nutrition-related research also applies to species other than salmonids.

Quality of Fish from Aquaculture Facilities

Research is required on differences in the overall quality of wild stocks and fish raised in aquaculture facilities, as well as the factors (e.g., nutrition) responsible for these differences. There is also a need for development of initial processing facilities for use at aquaculture facilities to avoid pre-processing deterioration due to handling and transport of fish.

Shellfish

Immediate research needs in shellfish culture include work to ensure a plentiful and continuous supply of juveniles (seed) through improvements in hatcheries and nurseries, as well as increasing the efficiency of grow-out operations to make them more profitable. Research work in bivalve hatcheries and nurseries is required in the fields of controlled gonad maturation, nutrition of larvae and juveniles, disease control, as well as improvements in handling techniques along with long-term work in genetics.

Diversification of the Aquaculture Industry

In addition to these research areas necessary to address known concerns related to salmon and shellfish culture, there is a clear need for much more effort to be directed at diversification of the aquaculture industry. B.C. coastal waters support a very diverse assemblage of finfish and shellfish resources, and the aquaculture industry should take advantage of this diversity by increasing the range of products it is capable of marketing. Particular emphasis should be placed on those species that are unique to this part of the world or those species most suitable for culture because of favourable growth conditions in B.C. waters. Specific research requirements include: pilot studies on the culture of scallops; methods of increasing the larval survival of sablefish (black cod) to increase aquaculture opportunities with this species; mechanization of the harvest of mussels; determination of the cause of summer mortality in mussels; and identification of areas and methods for clam and scallop culture.

There are also substantial opportunities for production of edible marine plants and marine plant products (e.g., Lambda carrageenin) by kelp farming in B.C. In some cases, the favourable climatic conditions on this coast may lead to development of profitable enterprises for a comparatively small investment of research funds.

Interrelationships between Aquaculture and Water Quality

In addition to R & D needs directly related to the aquaculture industry, there are clear interrelationships between this sector and concerns discussed earlier in relation to water quality. Investors in this industry and the public have concerns regarding the effects of water quality on the growth potential of finfish and shellfish, as well as the possibility for

uptake of contaminants by cultured marine organisms, both of which could adversely affect the success of aquaculture operations. However, in general, water quality appears not to be a threat to this industry because contaminant concentrations are low and flushing rates are relatively high in most B.C. coastal waters.

Interactions between phytoplankton and shellfish/finfish populations are one area where further research is required. High densities of phytoplankton in sea water can interfere with respiration of marine organisms by clogging of gills and may cause mortality of affected individuals by suffocation. The entire problem of shellfish poisoning and its associated human health risks is also an area where further research is needed, including the detection of accrual of toxins in muscle tissue and possibly its neutralization.

Research carried out in conjunction with other Science Council sectors will interact with beneficial results to the aquaculture sector.

Constraints to Further Research

There are several factors that are currently hampering research relevant to the aquaculture industry in B.C. These are:

- The constraints faced by the aquaculture industry rapidly change, especially in the high growth areas such as salmon farming. In the absence of coordination, there is a risk that the limited funds available will not be directed at key areas.
- There are a large number of agencies and research organizations involved in aquaculture-related projects in the province. In some cases, coordination of the efforts of various groups is hampered by the limited communication among these organizations.
- Much of the research necessary for the salmon-farming industry must take place in sea water and in conditions comparable to those that exist under actual production regimes. In addition, nutrition and disease research frequently requires large numbers of environmentally-controlled tanks. At present, there is only one experimental farm in the province (Pacific Biological Station) and this facility is fully used. This shortage of suitable space for research projects necessitates conduct of research at actual fish farms, which may then lead to conflicts with production objectives. Additional facilities are needed.

Recommendations

The following recommendations on aquaculture research and development are based on our assessment that aquaculture is a promising new industry. In contrast to established industries, substantial levels of support for research and development will be important to ensure that B.C.'s aquaculture industry becomes internationally competitive as quickly as possible and remains competitive. Research should focus on studies that ensure the:

1. Resolution of existing problems and provision of new opportunities in the salmon-farming industry related to: (a) breeding practices and the genetics of artificially-reared stocks; (b) bacterial kidney disease and other diseases that affect fish survival and growth; (c) the nutritional requirements and options for maximizing the growth and health of pen-reared salmonids through improvement of diet, and in the long term, for developing alternative diets; and (d) differences in tissue quality of wild stocks and fish raised in aquaculture facilities, as well as the causes of these differences.
2. Development of a profitable shellfish culture industry through improvements in hatcheries and nurseries, research on reproduction, disease control, genetics, and handling techniques.
3. Diversification of the aquaculture industry through investigation of the technology required to artificially rear and harvest finfish other than salmon, various shellfish species, and marine plants.
4. Resolution or mitigation of present concerns related to fish kills resulting from high-density phytoplankton blooms, as well as shellfish poisoning and associated human health risks from uptake of toxins produced by phytoplankton.

CONCLUSIONS AND RECOMMENDATIONS

This report identifies additional research and development needs within the aquatic sector, including constraints to further research and specific recommendations of the committee in each of five areas expected to benefit the most from future R & D activities. These areas are water quality, aquatic instruments and devices, fish harvesting, fish processing, and aquaculture.

Water Quality

Research needs related to water quality and long-term pollution hazards in B.C. coastal marine environments will depend on industrial growth in the province. The committee concludes that the most significant local concerns that may require further investigation are: (1) the potential effects of relatively new contaminants from changes in the use of industrial chemicals (e.g., tributyl tin [TBT]); (2) adverse impacts of aquaculture operations in areas of limited water circulation; and (3) the natural occurrence of undesirable plankton blooms.

Aquatic Instruments and Devices

Because this industry is considered an integral part of the entire aquatic sector, R & D activities by local firms should be given the necessary financial support. We recommend: (1) continued development of devices and instruments supporting other B.C. aquatic sector industries such as aquaculture; (2) further research on acoustics instrumentation and fibre optic sensors; (3) increased technology transfer and cooperation among the universities, government agencies, and R & D firms engaged in this field; (4) greater funding of efforts to take highly promising products from the prototype to marketable stage of development; and (5) increased cooperation and interaction where appropriate with the electronics and manufacturing sectors within the province.

Fish Harvesting Industry

Major efforts are needed to eliminate potential disincentives arising from existing regulations and harvest techniques. It is recommended that special emphasis be given to the development of more effective harvesting and pre-processing methods. In addition, further cooperative efforts between the electronics sector and this industry should occur in the application of communications technology to enhance information exchange between the harvest and processing sectors, particularly in terms of composition and size of the catch and vessel tracking.

Fish Processing Industry

Additional R & D effort will increase the yield and improve the quality of fish products from fish processors. Incremental improvements in final product recovery will result in significant economic benefits, and increased processing efficiency will also be reflected in higher fish quality. The latter is considered very important because of consumer expectations. At the same time, there is a clear need for R & D efforts to be directed at: (1) new fish products and by-products using presently under-utilized resources; (2) innovative techniques to improve fish quality and extend product shelf-life; and (3) new packaging concepts for existing and future fish products. Opportunities for collaborative R & D programs involving the processing industry, government, and academic institutions should be pursued in an effort to stimulate the necessary research in the above areas.

Aquaculture

There has been rapid growth in the B.C. aquaculture industry over the past 15 years, as well as a significant potential for long-term economic benefits, investment incentives, and employment opportunities in B.C. This could be a billion dollar industry within the next two decades. However, certain existing problems must be resolved to achieve this potential and to ensure continued growth and competitiveness of the industry in world markets. This committee concludes that there is a strong existing base in terms of facilities and expertise for further R & D activities related to aquaculture in the province, as well as substantial benefits to be derived by the industry from various areas of research.

It is recommended that Science Council give support to future R & D efforts in four priority areas:

1. genetics and biotechnology, disease, nutrition, and quality of salmon reared in aquaculture facilities;
2. improvements in hatcheries and nurseries to ensure a plentiful and continuous supply of juvenile shellfish (seeds), as well as increasing the efficiency of grow-out operations; research is also required in controlled gonad maturation, nutrition of larvae and juveniles, and disease control, as well as improvements in handling techniques and long-term genetics;
3. diversification of the aquaculture industry through investigation of the technology required to rear artificially and harvest finfish other than salmon, various shellfish species, and marine plants; and
4. research related to fish kills resulting from high-density phytoplankton blooms.

Finally, this committee recommends that an Aquaculture Network be established to provide the framework for collaborative R & D to provide the necessary support for this growth industry in British Columbia. Our rationale for this recommendation is described in detail in the remainder of this report.

PART II
NETWORK OF EXCELLENCE

Background

The Natural Sciences and Engineering Research Council (NSERC) has proposed the establishment of a number of Networks of Excellence across Canada to provide the institutional framework for collaborative research in specialized areas. These networks would be formed to focus research on high-priority areas, attract and retain experts within a given field, consolidate and expand physical facilities and equipment, and provide the necessary support for growth industries that rely on R & D for their continued economic viability.

On the basis of the information presented in the previous sections of this report, it is clearly evident that the Aquaculture Industry is an ideal candidate for a Network of Excellence and that British Columbia provides a unique opportunity for establishment of such a collaborative framework for future R & D activities. There are persuasive reasons for this conclusion:

1. The aquaculture industry has an enormous potential for producing long-term economic benefits, investment incentives, and employment opportunities in B.C. However, certain existing problems must be resolved to achieve this potential and to ensure continued growth and competitiveness of the industry in world markets.
2. There are active and growing aquaculture-related R & D activities by government scientists, universities and colleges, the private sector, and the industry itself; an informal network already exists among these groups in terms of joint research initiatives and a range of extension programs. A Network of Excellence is needed to strengthen these relationships.
3. Technology transfer and extension activities of the federal and provincial governments, and aquaculture degree, diploma, and instruction programs at academic institutions already exist, and would not only benefit greatly from establishment of a Network of Excellence for Aquaculture within B.C., but also provide much of the necessary framework for its formation and development.

4. There is enthusiasm within the industry for application of new technology and scientific advice, and the scientific and technological expertise necessary for further development of the industry already exists within B.C.
5. The province has 26,000 km of coastline and much of it is sheltered with favourable temperature ranges and climatic and oceanographic conditions for aquaculture; at the same time, coastal waters of B.C. support a diverse assemblage of finfish and shellfish resources that may be the focus of future aquaculture research projects and industries.

Overview of Aquaculture-Related Activities in British Columbia

Department of Fisheries and Oceans - DFO has been actively conducting research on shellfish and finfish aquaculture for the past three decades, with research on salmonid aquaculture occurring before the actual development of the salmon-farming industry in the province, and is the principal focus for aquaculture research in British Columbia. The priority research areas have included culture technologies (including incubation technology), fish and shellfish health, nutrition and diet development, brood stock development, water quality requirements, growth acceleration, genetics, and biotechnologies. The transfer and rearing of salmon smolts in sea pens has also been a focus of DFO investigations, and research on environmental issues associated with salmon netpen farming has recently been initiated. This research has been conducted and is ongoing at the Pacific Biological Station (Nanaimo), West Vancouver Laboratory, and the Rosewall Creek experimental facility of DFO. Within DFO, the Pacific Region Science Sector (Nanaimo and West Vancouver) has been designated the National Centre of Disciplinary Excellence for research in Biotechnology and Genetics for Aquaculture. In addition to salmon aquaculture, the activities of DFO scientists have included research on culture of oysters, clams, roe herring, herring roe on kelp, and halibut, with current emphasis on research on scallop, mussel and sablefish culture. DFO also is involved in undergraduate and graduate student training in aquaculture-related areas, in co-operation with all three B.C. universities and Malaspina College as well as universities from outside the province or country. Through its Subvention Program and financial contributions to the unsolicited proposal program of the Federal Department of Supply and Services, DFO supports university-based and private sector research in aquaculture.

The DFO Pacific Region Science Sector is now working closely with the B.C. aquaculture industry and has established an aquaculture industry-DFO research advisory committee. DFO also has close research links with private sector companies, B.C. Research, and the provincial government aimed at developing high technology products for use in the aquaculture industry.

The establishment of an Aquaculture Centre on the site of the Pacific Biological Station, but managed independently of the Station and outside the Federal Government system, has been planned and is ready to proceed, pending support of the concept by the Provincial Government and the B.C. Aquaculture industry.

DFO also has cooperative research agreements, for various areas of aquaculture, with Norway, the Soviet Union, and the U.S.A.

Provincial Government - The B.C. government has funded and conducted a number of aquaculture research projects. It is supporting a Chinook Broodstock Strain Comparison project in collaboration with DFO, B.C. Research, and the B.C. Salmon Farmers Association. It is also funding the Chinook Broodstock Development Plan being conducted by the B.C. Salmon Farmers Association, with technical direction by DFO and U.B.C. staff. The provincial government also has funded research conducted at DFO's Pacific Biological Station on oysters, mussels, and clams, and is currently providing partial support for research to develop scallop culture methodology and for studies on diseases and parasites of shellfish. In addition, the provincial government has been involved in extension work and technology transfer in aquaculture, including research on fish health.

Other Collaborative Programs - The technology developed to date by the B.C. aquaculture industry, universities, and government agencies has made a significant contribution to international aquaculture projects. There are numerous examples of programs such as those funded by the Canadian International Development Agency (CIDA) and the International Development Research Centre (IDRC), where B.C. aquaculture specialists have used technology developed within the province to assist in similar ventures overseas.

B.C. Research - Some base-budget funds of B.C. Research are directed at aquaculture research, while other studies are conducted under contract to the province and the aquaculture industry itself. The two primary areas where B.C. Research has been active are in broodstock work and fish health, particularly in disease screening.

Malaspina College - Malaspina College in Nanaimo has been active in the aquaculture sector for several years. It offers a 2-year training program in Aquaculture and Fisheries Technology, and is involved in disease screening of salmon broodstock for the B.C. Salmon Farmers Association. Research on sturgeon culture is conducted by college staff and students. An informal arrangement for technology transfer between the Pacific Biological Station and Malaspina College has existed over the last few years.

Universities - Aquaculture-related topics have often been included in fisheries and biology courses offered for a number of years by the three B.C. universities. However, each university now has specific undergraduate and/or graduate programs that provide training in the aquaculture field. An aquaculture course, covering a broad spectrum of subjects, is taught at the University of Victoria; a masters level program and some undergraduate courses

in aquaculture, including special courses on nutrition, aquacultural economics, resource management, and diseases are offered at Simon Fraser University; and the University of British Columbia has initiated an undergraduate aquaculture program. In addition, research on fish nutrition has been conducted at the Animal Sciences Department, U.B.C. for several years, and there has been much other work applicable to aquaculture at this institution. Simon Fraser University has conducted research on seaweed culture and recently initiated research on salmon diseases and their control in aquaculture, as well as on growth and nutrition. An Institute of Aquaculture also has been established recently at Simon Fraser University. The general research capacities of each university in many fields are also of considerable benefit to the aquaculture industry.

Western Canadian Universities Marine Biological Society (WCUMBS)- Research on marine plants and shellfish aquaculture, in cooperation with industry, has been conducted at the Bamfield Marine Station on the west coast of Vancouver Island. During the past 15 years, numerous reports on aquaculture-related research have been published and several aquacultural enterprises have begun or are at a pilot scale level of development. Plans are currently underway for expanded R & D work, supportive of the aquaculture industry, especially on marine plants, invertebrates, and alternate fish species.

Aquaculture Industry - The industry conducts some salmon broodstock research itself and provides funds for work on salmon disease screening. It also has conducted research on shellfish culture, particularly development and improvement of bivalve hatcheries, devising methods to collect natural sets of bivalves, development of a nursery system, and improvement of grow-out technology for oysters, scallops, and clams.

B.C. Salmon Farmers Association - This association promotes aquaculture research and contributes to the planning and funding of such research. It also assumes a role in the transfer of information and technology related to salmon aquaculture through preparation and distribution of information brochures and technical manuals and organization of workshops.

Establishment of an Aquaculture Network

The concept of networking and the establishment of networks comprise a set of practical techniques to achieve strategic goals. Here, networks may be defined as the institutional framework for coordinated and collaborative research in specialized areas when the expertise is found within several organizations or at a number of sites in the same general region. There are many approaches to networking. The literature on networks is vast and most of it pertains to the communications aspects (i.e., transfer of technology and data), rather than the organizational models which can make best use of this administrative structure.

The objective of the network would be the enhancement of aquaculture as a commercial endeavour in British Columbia through the matching of industry needs and R & D capabilities to solve the existing problems and develop new opportunities, as well as to the transfer of technical findings to the user. Cooperative thrusts by industry, research and education could further enhance development of the excellence already existing in aquaculture within British Columbia.

To meet the aforementioned objectives, a potential model might include the following elements:

- Industry input
- Technical assessment
- Research/educational groups
- Technical transfer
- Support funding
- Monitoring
- Coordination including networking and administration

Participation in the network would not preclude any organization from seeking and using separate funding (e.g., as in areas involving proprietary research).

Early benefits of an aquaculture network would include:

- efficient use of expanded R & D funding
- effective joint participation in solution of core industry R & D problems (e.g., the BKD disease problem)
- satisfaction of industry requirements for technical knowledge and personnel (e.g., educational and academic fellowships)
- enhancing experimental facilities for fish, shellfish and plants (e.g., several sites and facilities requiring support).

There is widespread interest within industry, government, and the educational community for cooperative and collaborative aquaculture research. Several substantive analyses document existing enthusiasm and support. Only the critical funding is lacking. Ample expertise exists to develop the functional components in a more substantive way but it is important that such an effort consider all potential participants. Therefore, it is suggested that an ad hoc body be formed, possibly under the aegis of the Science Council, to provide details of a functional model and seek the response of the aquaculture community. This task would require a relatively small amount of funding but needs a statement of conditions of potential support. We believe that any of the alleged areas of difficulty in networking could be resolved through this process.

Implementation of the aquaculture network within a reasonable time frame would require only formal adoption of the mode of the network and core funding. The people and physical facilities are in place to inaugurate this proposal.

Conclusions and Recommendations

The Aquatic Resources Sector Planning Committee highly recommends establishment of a Network of Excellence for Aquaculture in this province. This Network could coordinate the efforts of various complementary research groups and attract additional expertise to the province. It would provide greater opportunities for interaction within the aquaculture research community, and lead to further industry confidence, economic benefits, and capital investment by virtue of a much broader base for future technological development and innovation. It could also assist in the identification of future research requirements, the most appropriate agencies or organizations to conduct this research, and possible avenues for funding of specific projects.

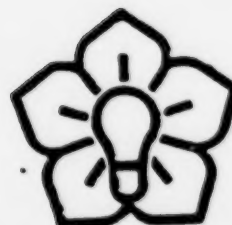
SUMMARY OF RECOMMENDATIONS
FROM ALL SECTORS

AGRICULTURE AND FOOD PROCESSING

RECOMMENDATIONS (CONT'D.)

- FUNDING FOR SECONDARY MANUFACTURE, FOOD PROCESSING
- RESEARCH ORGANIZATIONS STAFFING AND EQUIPMENT
- GENERAL AWARENESS
- TECHNOLOGY TRANSFER

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AQUATIC RESOURCES

\$750M INDUSTRY

AQUACULTURE - HIGH GROWTH
- SCIENCE ISSUES

RECOMMENDATIONS

- WATER QUALITY
 - SPECIFIC CONTAMINANTS
 - AQUACULTURE
- AQUATIC INSTRUMENTS AND DEVICES
 - INTERFACE WITH SECTOR
 - GROWTH AREA
- FISH HARVESTING
 - GOVERNMENT AND SOCIAL POLICIES
 - IMPROVEMENTS POSSIBLE
 - SHIP/SHORE COMMUNICATION



AQUATIC RESOURCES

RECOMMENDATIONS (CONT'D.)

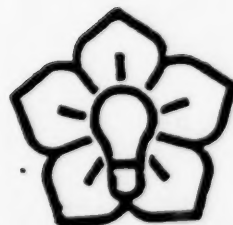
- FISH PROCESSING

- NEW PRODUCTS
- BY-PRODUCTS
- QUALITY
- PACKAGING

- AQUACULTURE

- INTERFACE WITH BIOTECHNOLOGY
 - DISEASE CONTROL
 - NUTRITION
 - GENETICS
 - WASTE MANAGEMENT
- NETWORK OF EXCELLENCE

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BIOTECHNOLOGY

EMERGING INDUSTRY - \$12M

IMPACTS ON MANY SECTORS - FORESTS

- AGRICULTURE
- AQUACULTURE
- HEALTH
- WASTE MANAGEMENT
- MINING

NEED FOR STRATEGIC PLANNING, CO-ORDINATION

RECOMMENDATIONS

- FOCUS ON
 - DISEASE CONTROL
 - GENETIC IMPROVEMENT
 - WASTE MANAGEMENT
- STRATEGIC PLANNING - USE OF EXISTING COMMITTEE
- LONG TERM COMMITMENT OF FUNDING
- RAISE FUNDING FROM \$10M TO \$30M - 5-10 YEARS

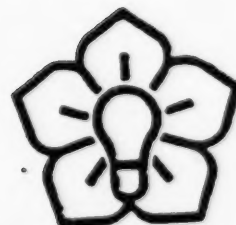


BIOTECHNOLOGY

RECOMMENDATIONS (CONT'D.)

- STRATEGIC RESEARCH, TRAINING, SCHOLARSHIPS
- INDUSTRY/UNIVERSITIES INTERACTION
- REVIEW FACILITIES NEEDS AND CO-ORDINATION

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ENERGY

MAJOR RESOURCE OF PROVINCE

DEPENDENCE OF OTHER RESOURCE SECTORS

OIL - IMPORT TO B.C.

NATURAL GAS SURPLUS

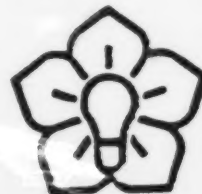
RECOMMENDATIONS

- OIL & GAS

- DEVELOP UNDERSEA ROBOTICS
- PREPARE FOR SWITCH AWAY FROM OIL
- NATURAL GAS DIESEL ENGINE CONVERSION

- COAL

- DEVELOP CAPABILITY TO ANALYZE COALS
- BENEFICIATION & TRANSPORTATION
- ALTERNATIVE USES



ENERGY

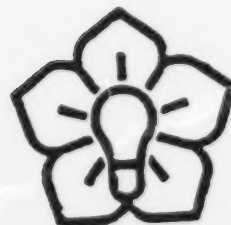
RECOMMENDATIONS (CONT'D.)

- WOOD RESIDUE AND BIOMASS
 - CONTINUE DEVELOPMENTS -
METHANOL, ETHANOL
- OTHERS
 - HYDROGEN
 - FUEL CELL

SCIENCE & TECHNOLOGY ENERGY FOCUS

- CENTRE FOR ENERGY STUDIES
- BUILD EXPERTISE
- UNDERTAKE TESTS
- NATURAL GAS
- LONGER TERM ITEMS

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FORESTS AND FOREST PRODUCTS

GROWTH AREA

MOVING TO VALUE ADDED PRODUCTS

RESOURCE DIMINISHING AND MORE EXPENSIVE

WORLD-WIDE COMPETITION

DEPENDENCE ON SCIENCE & TECHNOLOGY

ADVANCED MACHINERY AND SYSTEMS

PEOPLE NEEDS

RECOMMENDATIONS

- OVERALL CO-ORDINATION FOR SCIENCE AND TECHNOLOGY
- ADD VALUE
- IMPROVE PRODUCTION FOR RESOURCE

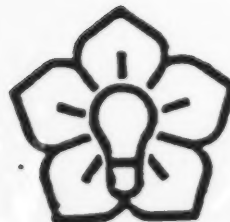


FORESTS AND FOREST PRODUCTS

RECOMMENDATIONS (CONT'D.)

- RAISE TECHNOLOGICAL AWARENESS AND COMPETENCE
 - RESEARCHERS
 - 'RECEPTORS'
- TECHNOLOGY TRANSFER
- USE OF ADVANCED SYSTEMS, TECHNOLOGIES AND MACHINERY

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INFORMATION TECHNOLOGY

\$1 BILLION INDUSTRY

11,500 PEOPLE

25%-50% ANNUAL GROWTH

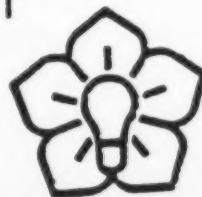
RESOURCE INDUSTRIES/INFORMATION TECHNOLOGY

PEOPLE NEEDS

CO-ORDINATED ACTIONS

RECOMMENDATIONS

- ENHANCE RESOURCE INDUSTRIES BY
ENHANCING THE INFORMATION TECHNOLOGY
INDUSTRIES
- COMMIT TO INFORMATION TECHNOLOGY
- MARKETING, MANAGEMENT, TECHNICAL
PEOPLE
- CO-ORDINATION AND PLANNING ROLE
- INFRASTRUCTURE AND SUPPORT



MANUFACTURING

IMPORTANCE TO PROVINCE

4,000 COMPANIES - 40 LARGE

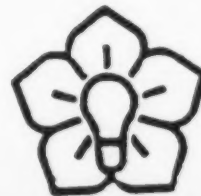
LACK OF TRAINING

DIFFICULTIES OF LOCATING PARTNERS

TECHNOLOGY TRANSFER - SMALL COMPANIES

RECOMMENDATIONS

- STRATEGIC PLAN - 'CHAMPION'
- BIOMEDICAL DEVICES
- EDUCATION AND TRAINING
- TECHNOLOGY CENTRE
- RESOURCE INDUSTRIES - ROBOTICS
- NETWORKING
- CAD/CAM
- FUNDING



MINING, MINERALS, METALS

NEEDS

- INDUSTRY INVOLVEMENT
- NATIONAL CO-ORDINATION
- FOCUS ON R&D
- RAISING AWARENESS

RECOMMENDATIONS

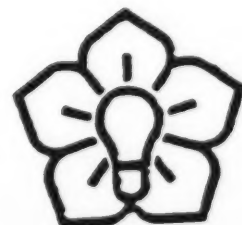
- R&D CO-ORDINATOR FOCUSSED ON B.C. NEEDS, NATIONAL INTERFACE
- INDUSTRY CHAIRS - ADVANCED MATERIALS
- CENTRES OF EXCELLENCE:
 - ADVANCED MATERIALS
 - INDUSTRIAL MINERALS
 - GEOLOGICAL EXPLORATION
 - RARE & PRECIOUS METALS



EMERGING THEMES

- BUILD ON EXISTING COMPANIES, ORGANIZATIONS AND INDIVIDUALS
- ORGANIZED STIMULATION OF INTERACTION AND PLANNING WITHIN AND BETWEEN SECTORS
- RESOURCE INDUSTRY FOCUSSED, TECHNOLOGY DRIVEN CENTRES OF EXCELLENCE
- VALUE ADDED PRODUCTS FROM RESOURCES USING TECHNOLOGY DEVELOPED IN B.C.
- DEVELOP THE MARKETING, MANAGEMENT AND TECHNICAL TALENTS OF OUR PEOPLE
- EFFECTIVE USE OF SIGNIFICANTLY MORE R&D SPENDING

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AGRICULTURE AND FOOD PROCESSING

PRIMARY AGRICULTURE

- ROLE OF AGRICULTURE CANADA
- VERY SMALL AVAILABLE LAND BASE

SECONDARY MANUFACTURE

- POTENTIAL GROWTH AREA

FOOD PROCESSING

- POTENTIAL GROWTH AREA

RECOMMENDATIONS

- INTERFACE WITH BIOTECHNOLOGY
 - DISEASE CONTROL
 - GENETICS
 - WASTE MANAGEMENT
- VALUE ADDED
 - FOOD PROCESSING
- INCREASE PRODUCTIVITY
- INCREASE INDUSTRY INVOLVEMENT
 - CO-OPERATIVE RESEARCH

